Time Sync distribution via PTP

Challenges, Asymmetries, Solutions

ITSF - 2011

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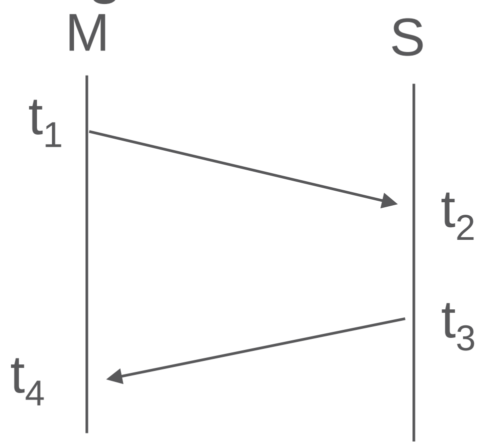
Time Synchronization via PTP, cont.

- The basic principle is to distribute Time sync reference by means of two-way time stamps exchange

Time Offset= $t_2 - t_1$ – Mean path delay

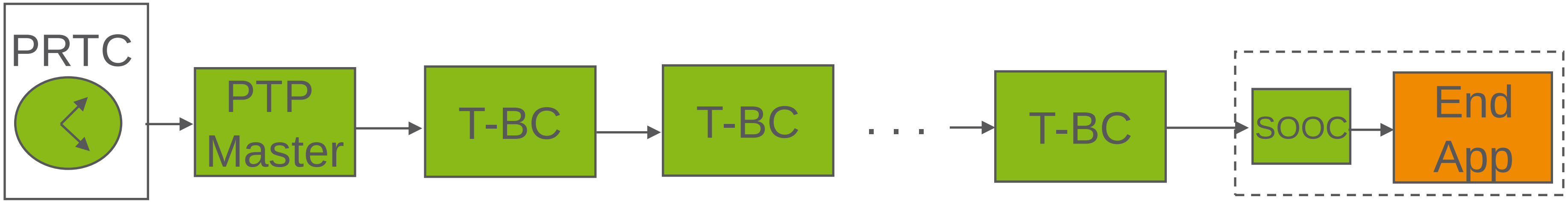
Mean path delay = $((t_2 - t_1) + (t_4 - t_3)) /2$



- As for NTP, also in case of PTP Symmetric paths are required:
  - Basic assumption: $t_2 - t_1 = t_4 - t_3$
  - Any asymmetry will contribute with half of that to the error in the time offset calculation (e.g. 3 μs asymmetry would exceed the target requirement of 1.5 μs)

Is “full IEEE 1588 support” good enough ?

- Removal of PDV and asymmetry in the nodes by means of IEEE1588 support (e.g. Boundary Clock in every node).



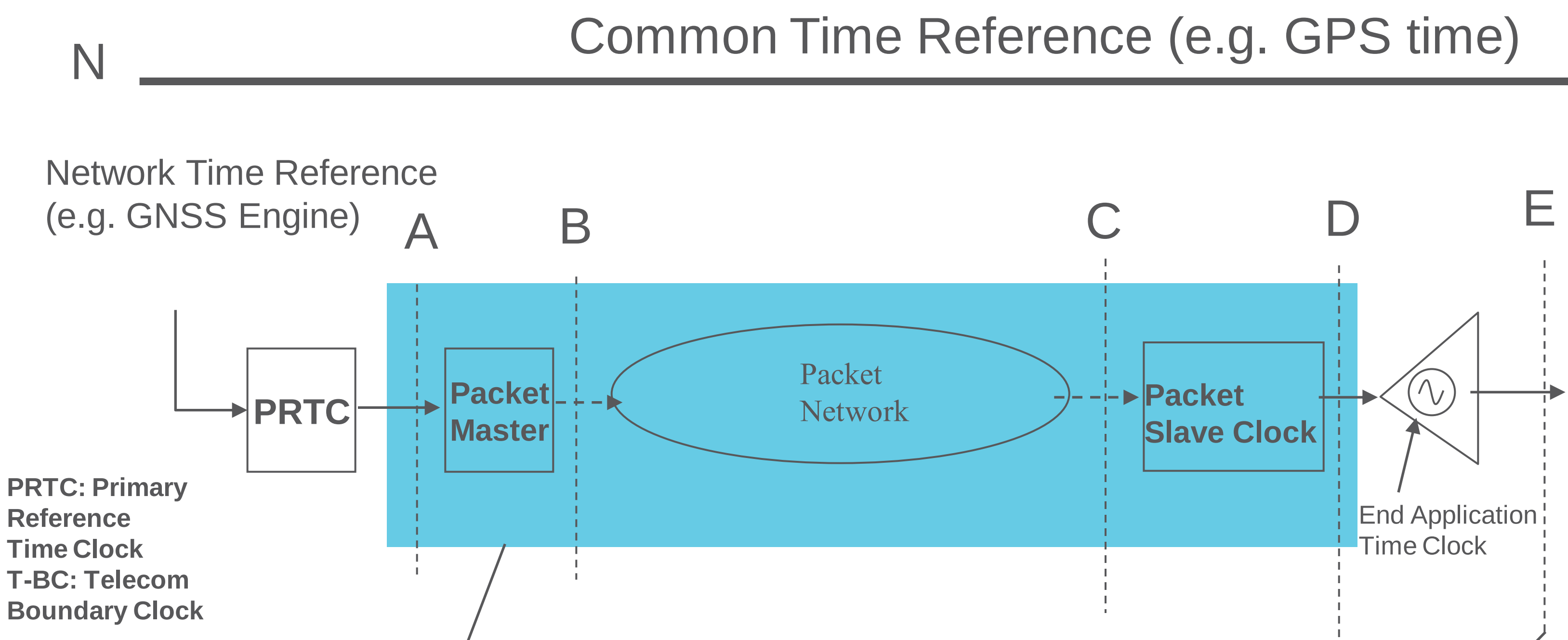
PRTC : Primary Reference Time Clock

T-BC: Telecom - Boundary Clock

SOOC: Slave Only Ordinary Clock

- Ideally the full support can provide very accurate timing, however several sources of errors still remains

Network Reference Model



Simulation Reference Model:

- chain of GM, 20 T-BC, SOOC
- with and without SyncE support

Typical Target Requirements $TE_E < 1.5\ \mu s$ (LTE TDD, TD-SCDMA)

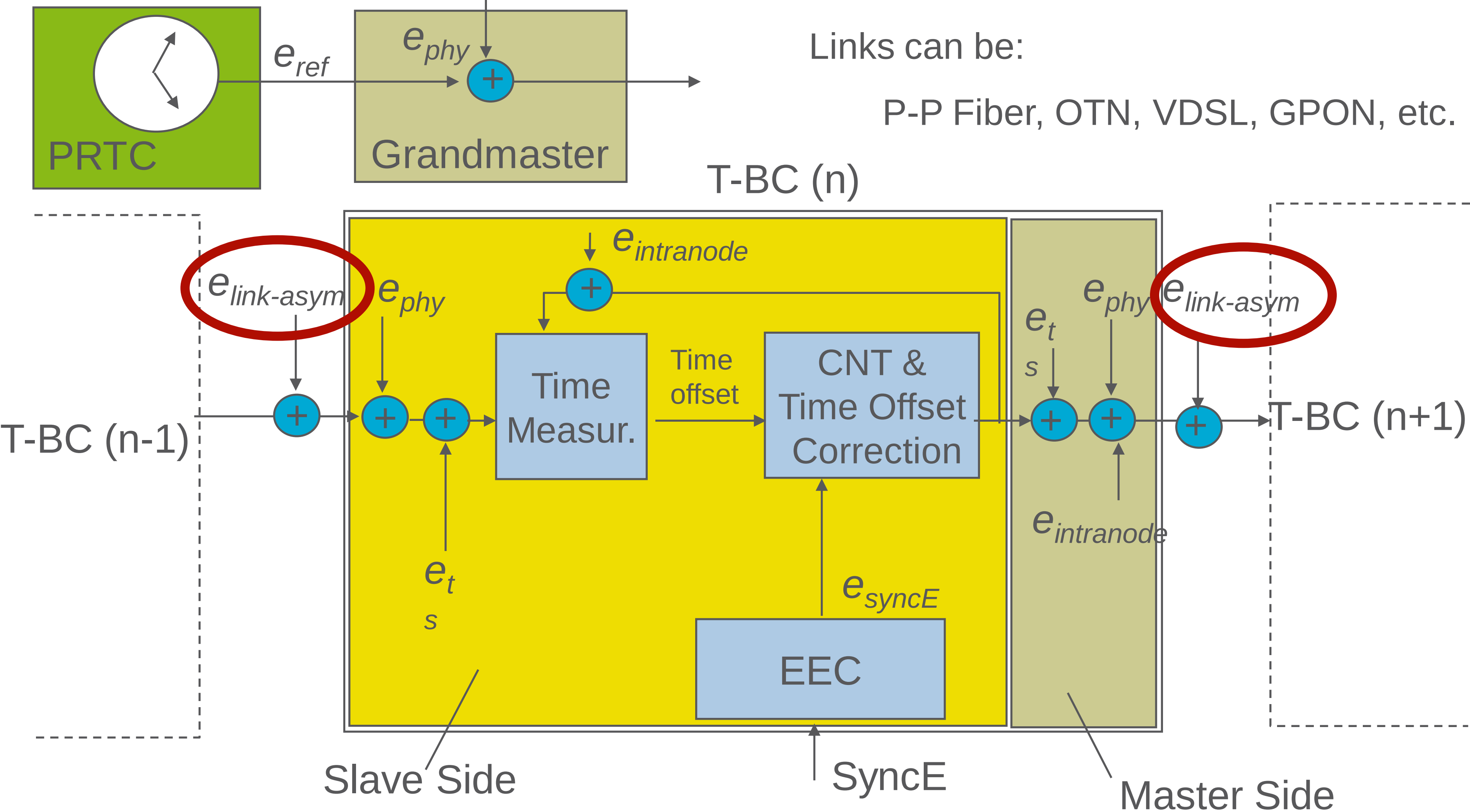
TE_D about $1\ \mu s$

$$TE_E = TE_D + TE_{DE} + TE_{HO}$$ (Holdover, Rearrangements)

Sources of Error

Links can be:

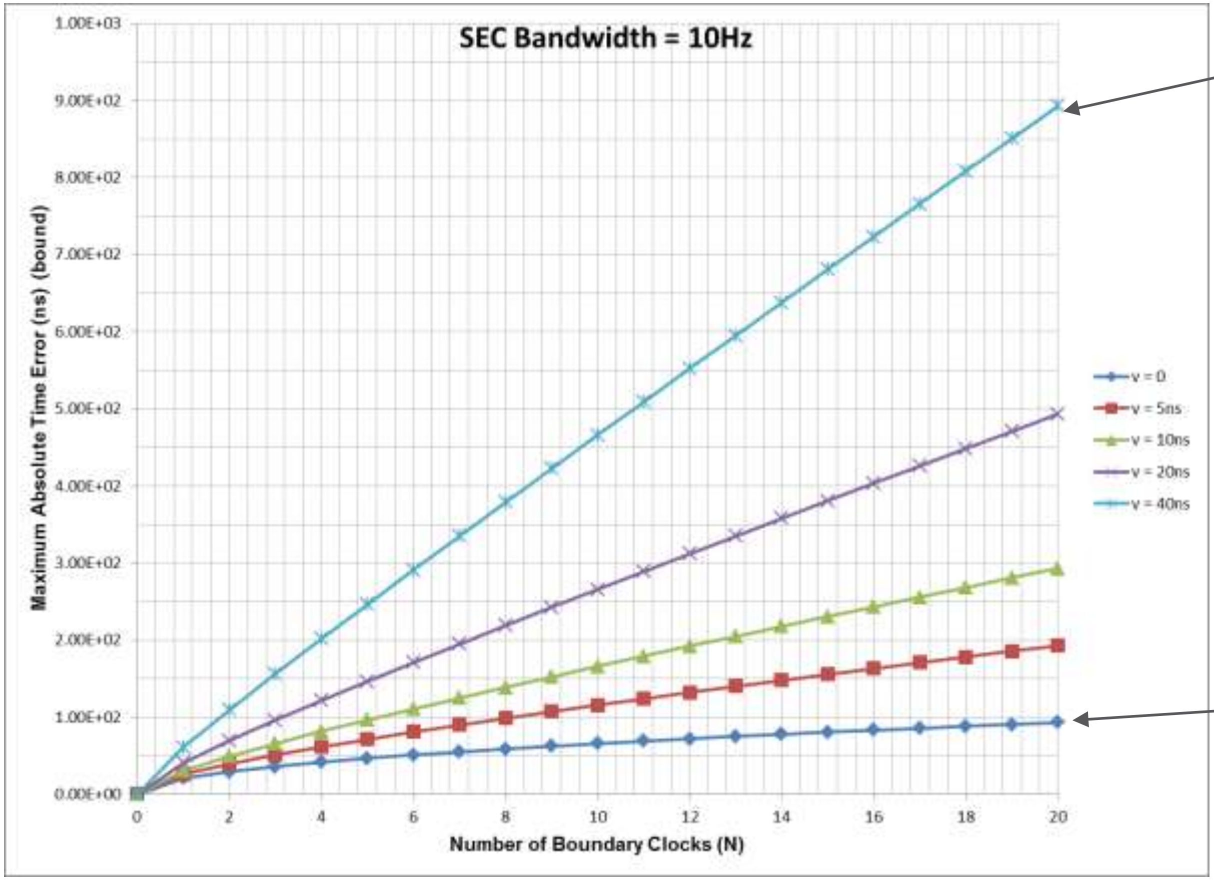
P-P Fiber, OTN, VDSL, GPON, etc.



Note: different models might be valid; discussions ongoing

Example of Time Error Accumulation

Accumulation of maximum absolute time error over a chain of boundary clocks for different values of asymmetry bias.
The physical layer assist involves SEC/EEC chain with bandwidth 10Hz.



40 ns asymmetry per hop

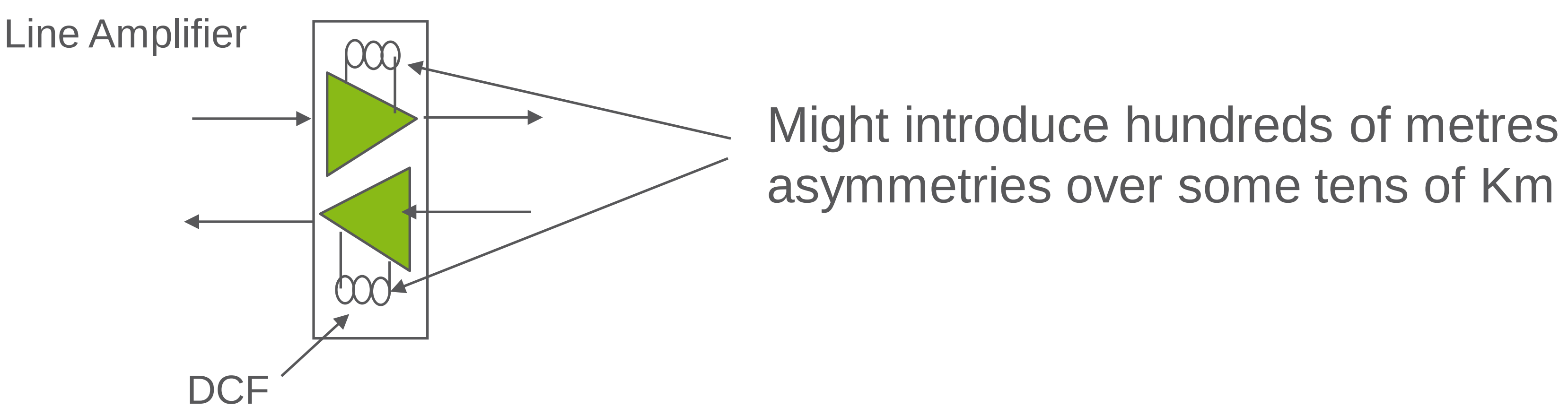
Source: WD25 (Anue), York, September 2011

no asymmetry
(only random noise)

v = max asymmetry per hop

Different fiber length and DCF

- Fiber length asymmetry is one major issue
  - About 2.5ns of inaccuracy per meter of asymmetry (related to group delay, about 5 ns/m)
- A line amplifier may embed a Dispersion Compensating Fiber (DCF) to compensate for the chromatic dispersion of the different wavelengths
  - the length of the fiber within DCF modules to compensate the same length of line fiber may vary significantly



Use of different Wavelengths

- Group Delay depends on the wavelength and different wavelength are used on the forward and reverse path
  - V = c/n (c= speed of light, n = group refractive index, depends on λ)
- $A = d_f - d_r = L * (n_r - n_f)/c$,
  - d_f and d_r are the forward and reverse transmission delay, and n_r and n_f are the related refractive indexes

Example:

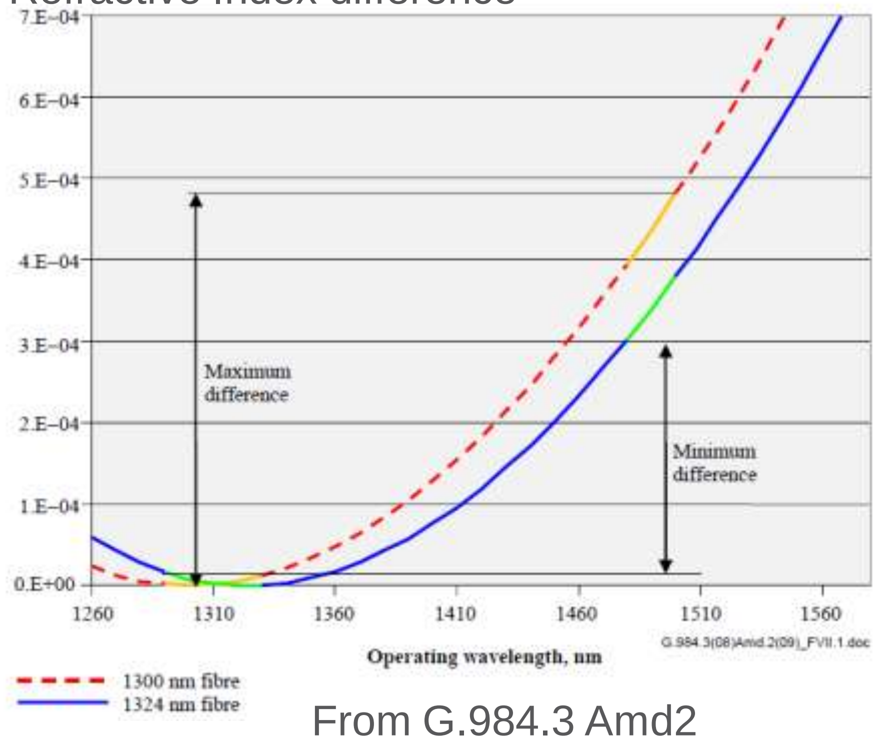
λ_r = 1529.94 nm; n_r / c= 2000 ps/Km

λ_f = 1611.79 nm; n_f / c = 3700 ps/Km

L= 50 Km

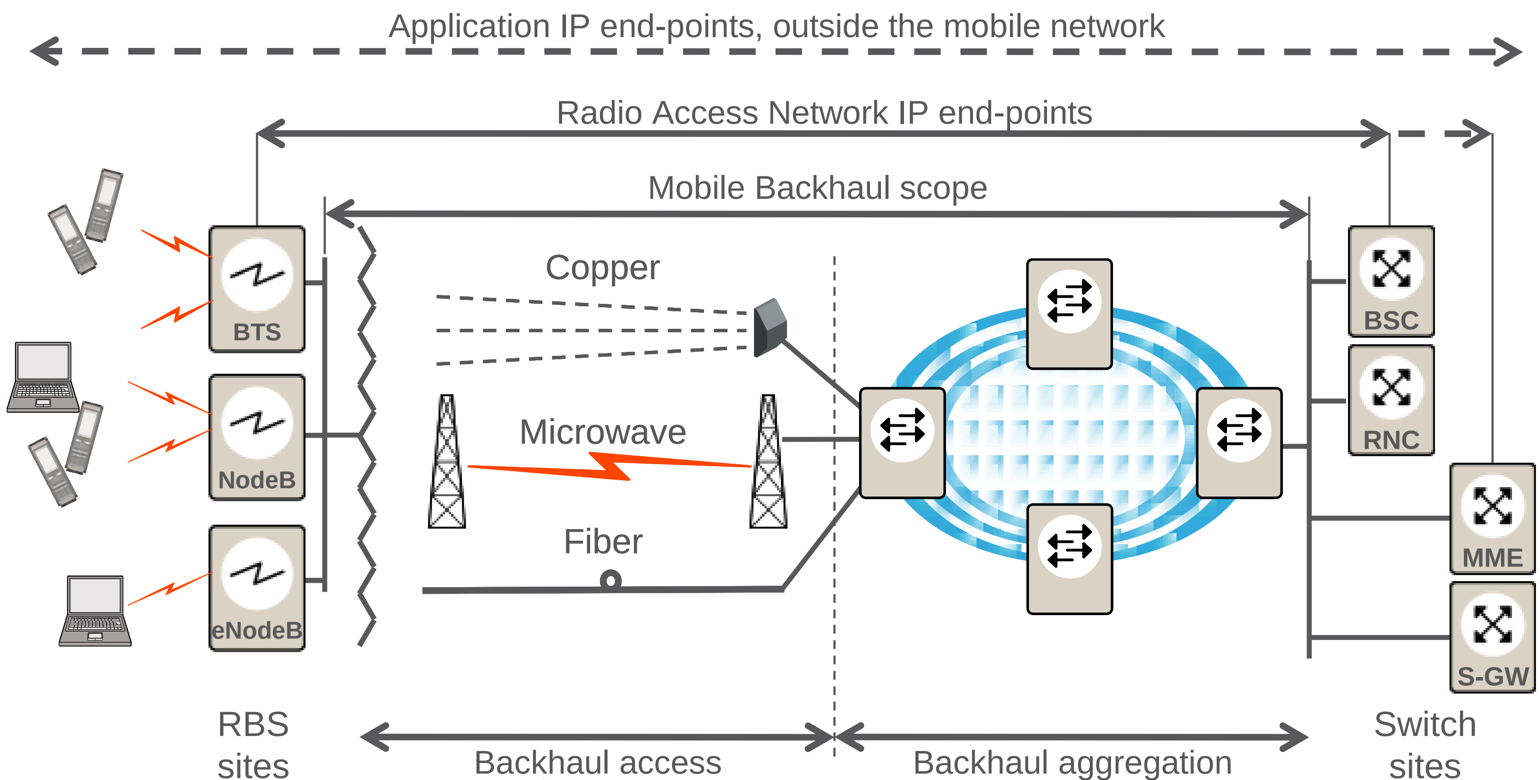
A= 1700 x 50 ps = 85 ns

Refractive Index difference



From G.984.3 Amd2

PTP over access technologies

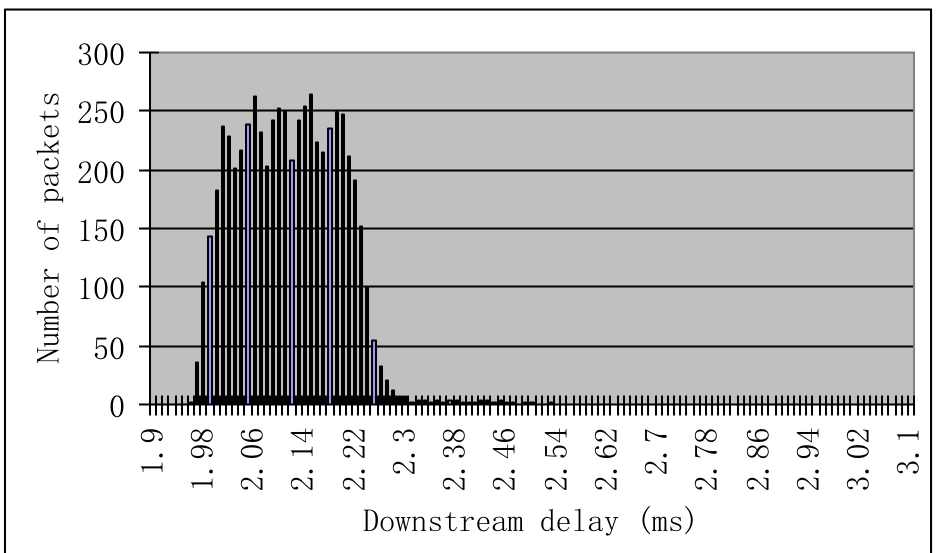


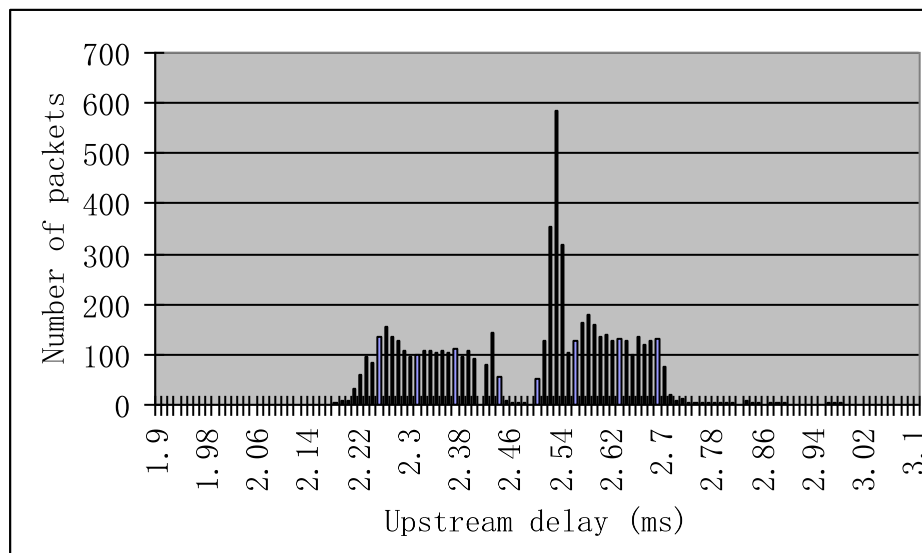
Some of the transport technologies used in the Backhaul Access can Introduce significant asymmetries

PTP over VDSL2

- VDSL2 add significant PDV and asymmetry (tens to hundreds of microseconds):
  - Encoding/Decoding FEC
  - Mapping onto DMT symbols
  - Symbols transmission/reception
  - Sync symbol
  - Transmitting user data to higher layer

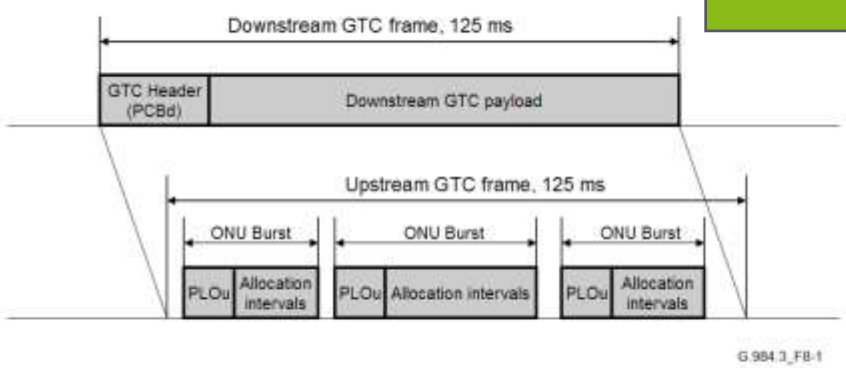
From 10GS-044 (China Unicom, MIIT), Asymmetry in Propagation Times of DSL Systems, (March, 2010)

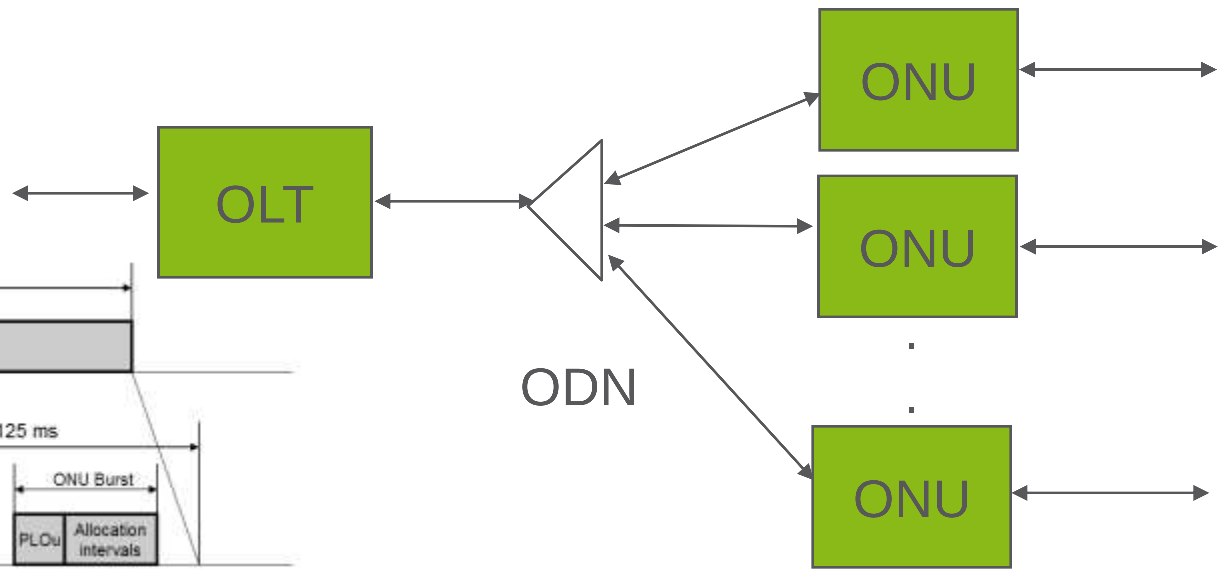




PTP over GPON

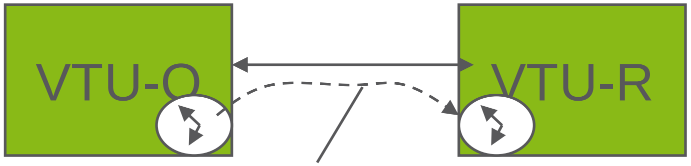
- Multipoint-to-Point Access Systems introduces Delay Asymmetry (hundreds of microseconds) mainly due to upstream scheduling protocols
- Upstream GPON Scheduling
  - The ONU is dependent upon grants from the OLT to send packets
  - The OLT issues regular grants on 125us cycles
  - Packets arriving too late for one grant must await the next, introducing delay and jitter





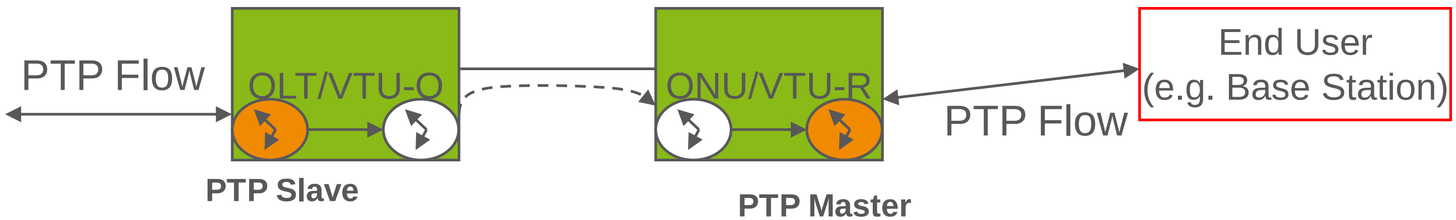
VDSL2/GPON solutions

- Several approaches have been proposed
  - "Distributed BC", "Distributed TC", "Discrete TC", "Delay Equalizer"
- Generally a common phase/time is shared between the remote ends:
  - Methods recently agreed in ITU-T:
    - G.993.2 Amd 7 (VDSL2) based on a two-way time stamp exchange with accuracy in the order of 100 / 200 ns;
    - G.984.3 Amd 2 (GPON) based on the ranging mechanism, with accuracy better than 100 ns

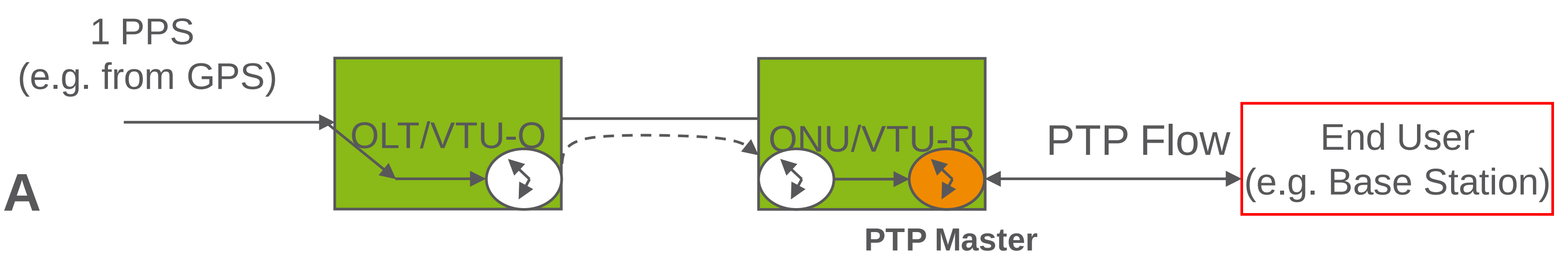


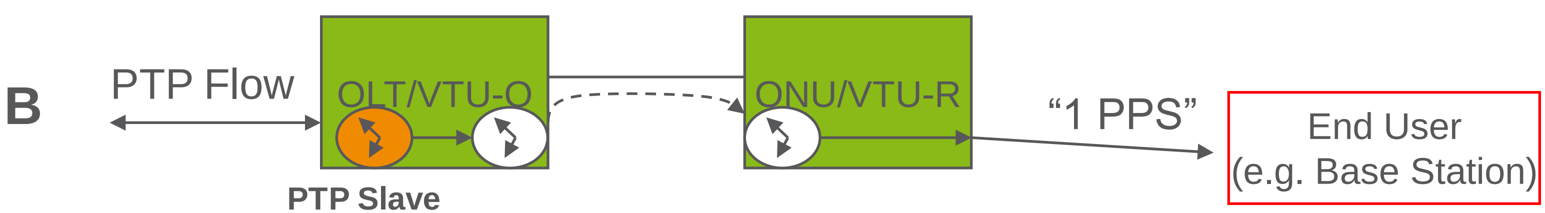
Distributed Boundary Clock

- Time is recovered at the OLT/VTU-O (PTP Slave); The “Local Time “ is locked to the external reference and used to synchronize the ONU/VTU-R
- All ONU/VTU-R implement a PTP Master that can be used to synchronize the End Users (e.g. Base Stations)



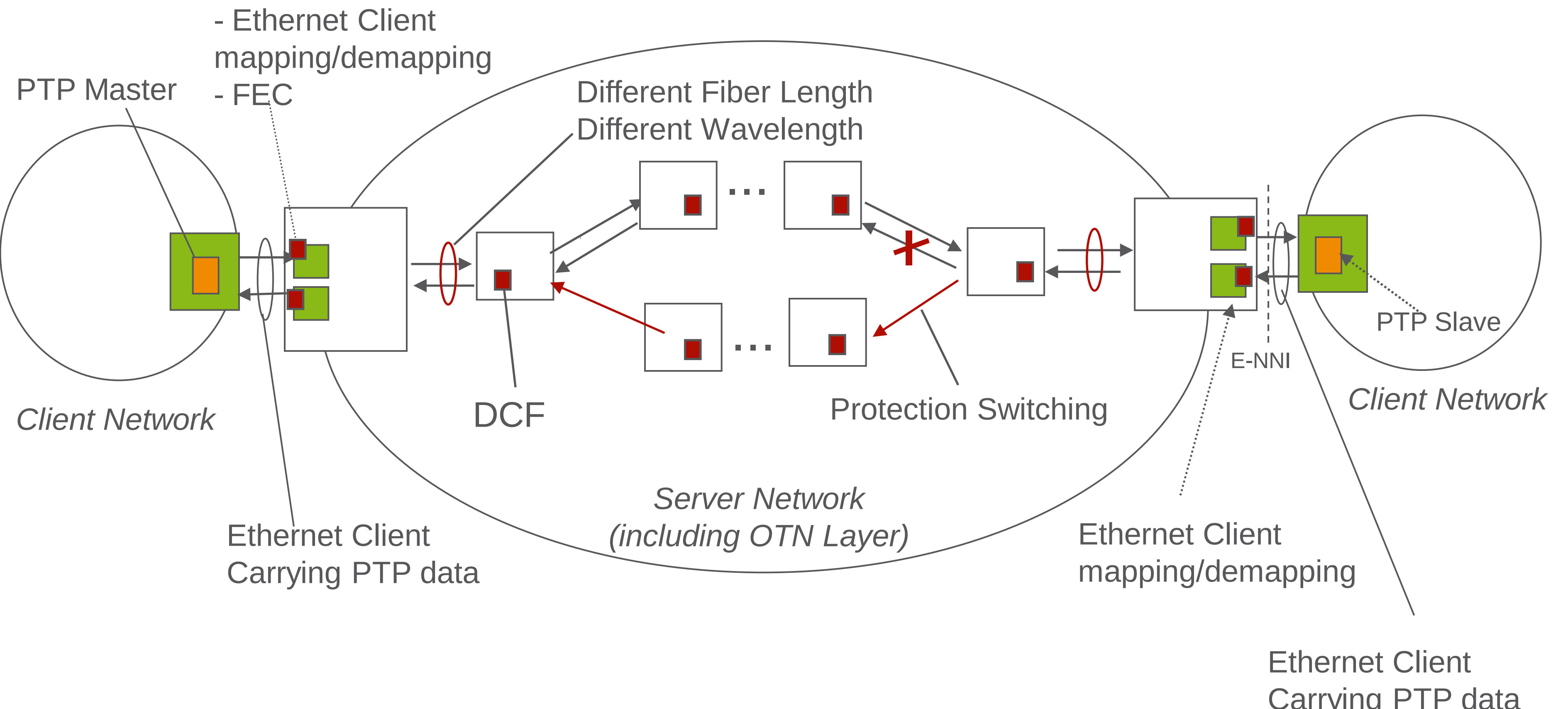
- Special cases :
  - A) Time Master co-located with the OLT/VTU-O (e.g. GPS receiver), directly delivering the time sync reference to the OLT/VTU-O
  - B) Time sync distributed to the End User from the ONU/VTU-R via a dedicated interface (e.g. “1 PPS”)





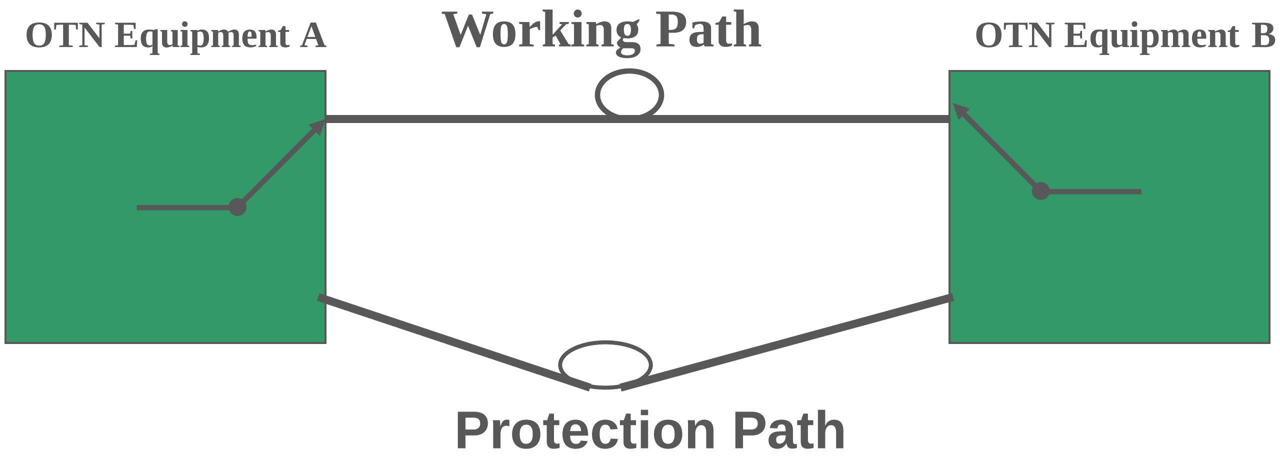
PTP over OTN

- The perfomance when carrying transparently PTP over OTN is under study
- Some source of delays (and asymmetry) being analysed



ODU Linear Protection

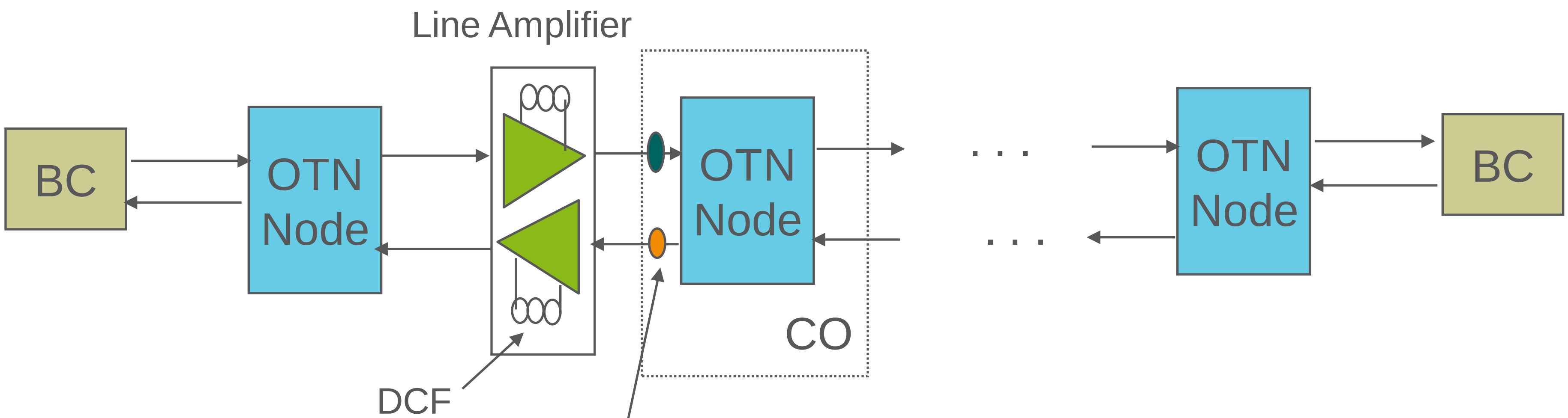
- Typical 1:1 Protection
  - Working and protection paths are not necessary congruent
  - This results in Asymmetry due to different paths



Bidirectional Protection can avoid this issue

Addressing Fiber Lengths and DCF

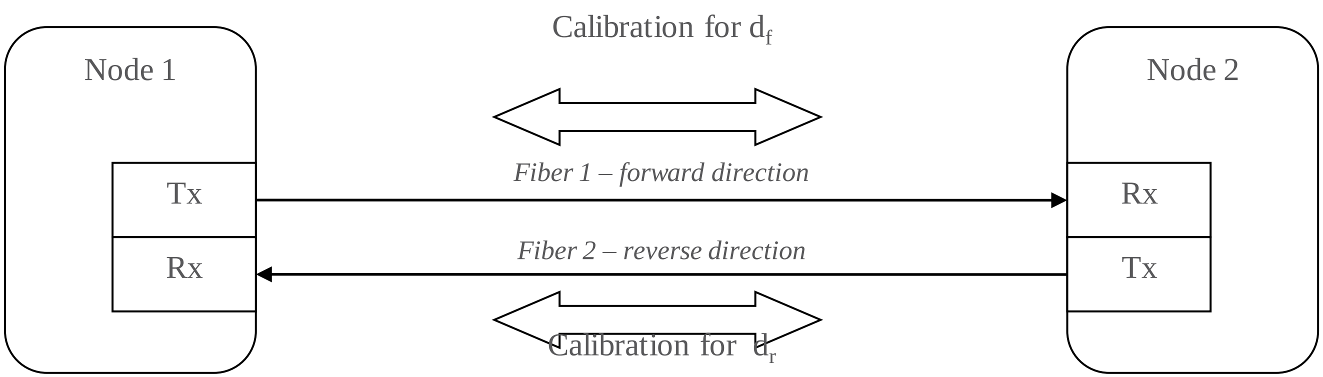
- Fiber Length asymmetry in the current field trials is manually compensated
- Not feasible (that may kill many PTP business cases)
- Solutions for automatic compensations have been discussed in ITU-T



fibers of different length may be used when connecting the equipments to the cables within a CO

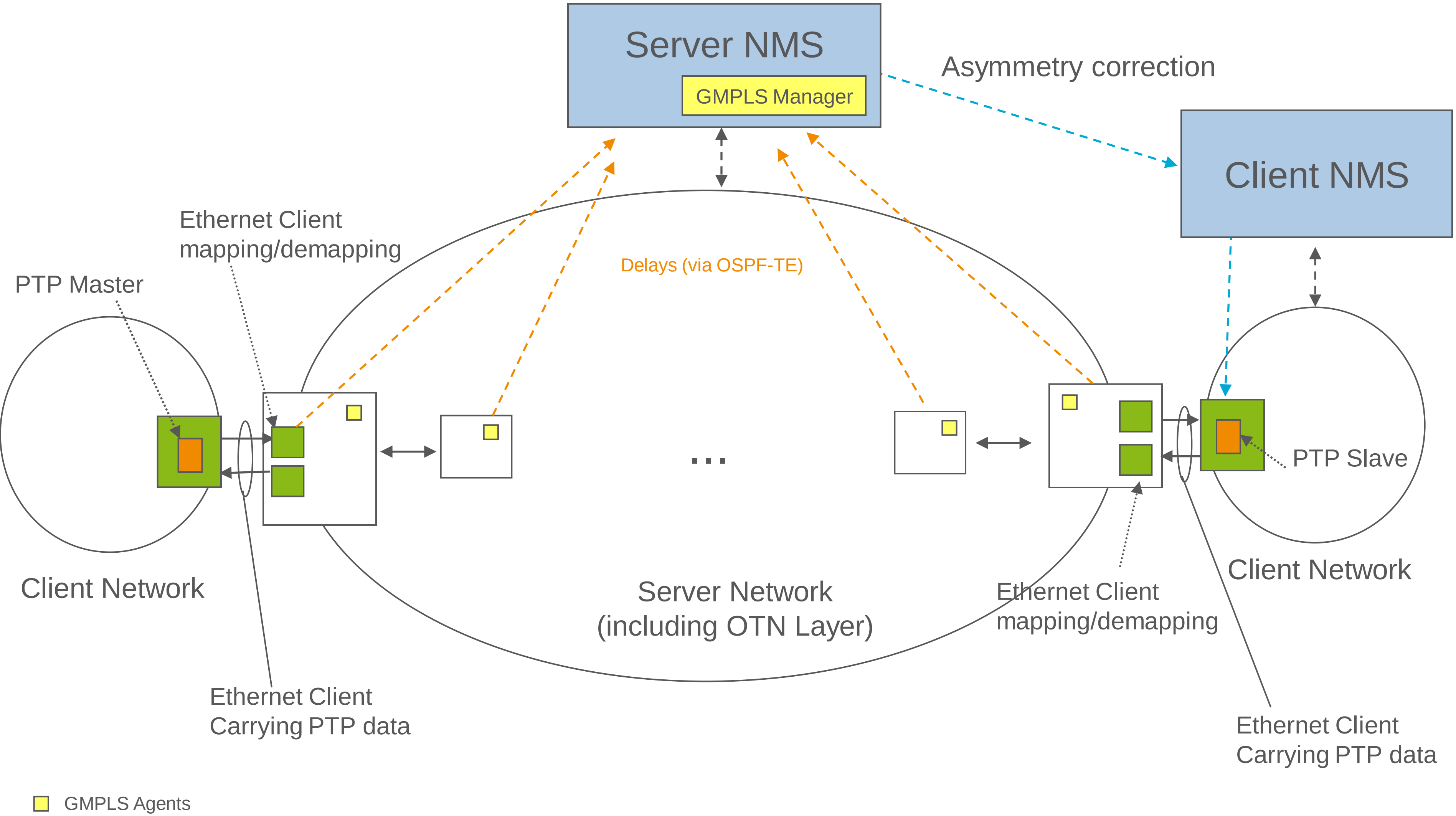
Fiber length and DCF Automatic Compensation

- Automatic link asymmetry calibration procedure in order to compensate for link delay asymmetry
  - based on calculating the propagation delays by means of two-way measurements made on the fibres used by the traffic.
  - Asymmetry information can be used locally (in case of BC) or delivered to the PTP clocks in the client network



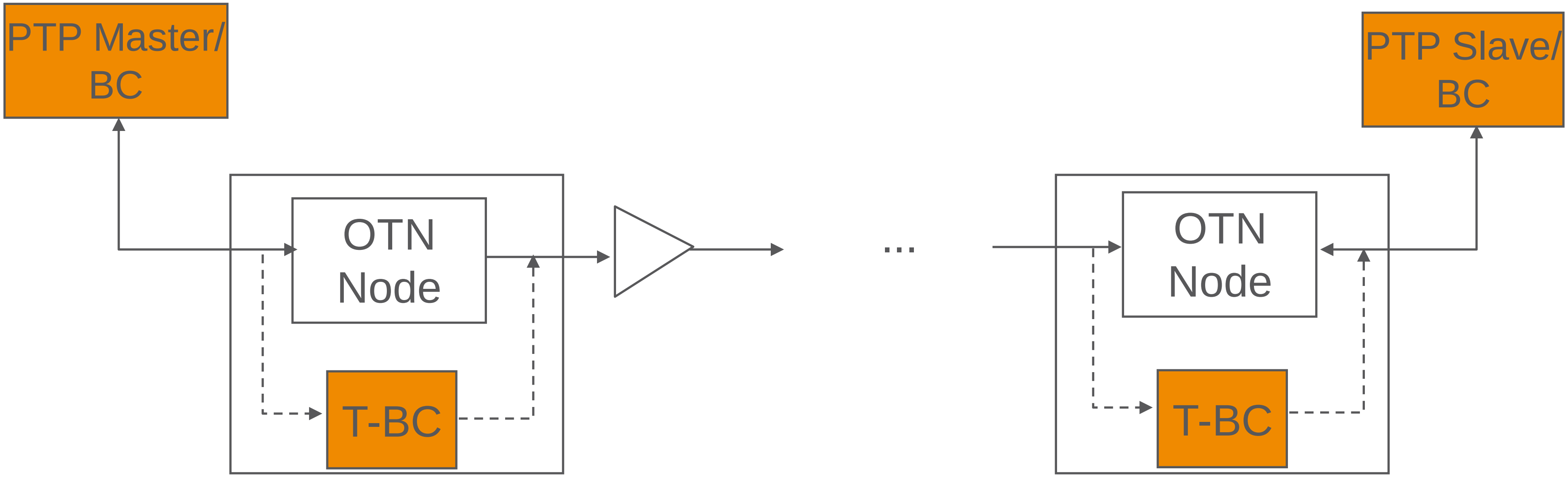
From G.8271 draft

Support from Control Plane



The Use of OTN Overhead to transport Sync packets

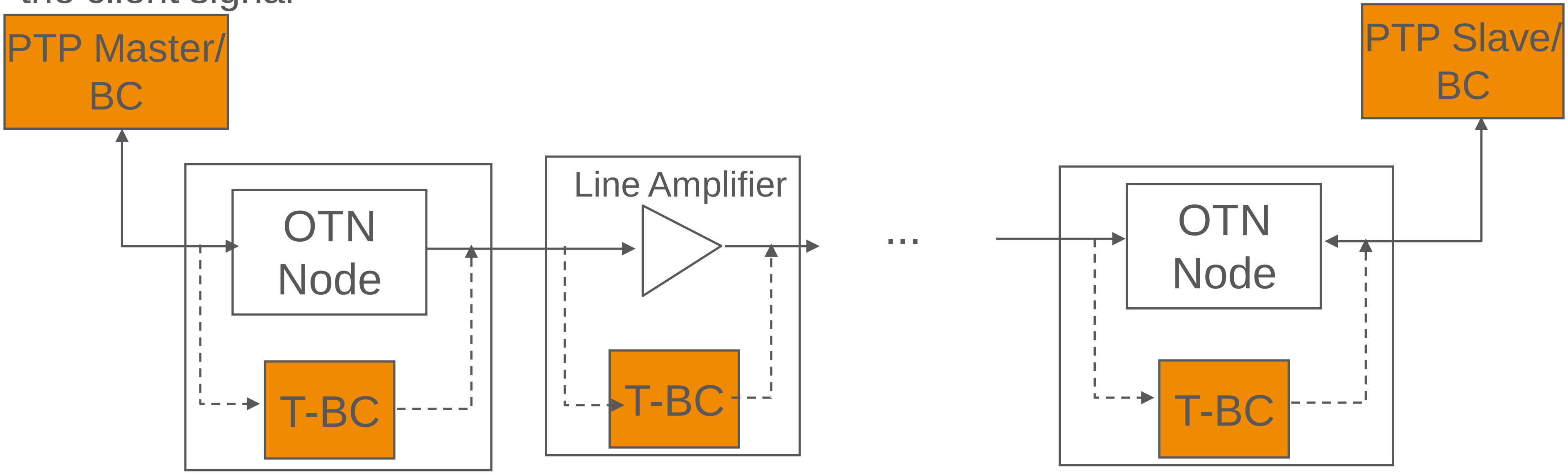
- PTP data is extracted from the client signal, processed and carried across the OTN network in the OTN Overhead
- The last OTN Node regenerates the client signal



- Characteristics
  - Timing is carried on different layers. Is this acceptable ?
  - Single operator only
  - Specific HW required in the OTN nodes
  - Asymmetries and noise due to OTN mapping/demapping and FEC are removed
  - Asymmetries due to fiber length and DCF are still to be addressed

The use of OSC to transport Sync packets

- PTP data is extracted from the client signal, processed and carried across the OTN network over the OSC (Optical Supervisory Channel). The last OTN Node regenerates the client signal



- Characteristics
  - Timing is carried on different layers. Is this acceptable?
  - Single operator only
  - Specific HW required in the OTN nodes and Line Amplifiers
  - Asymmetries and noise due to OTN mapping/demapping and FEC and DCF are resolved.
  - Asymmetries due to fiber length to be addressed
  - OSC is not fully standardized. <u>ITU-T has decided not to standardize this option</u>

Conclusions

- Increased interest on time distribution from the network
  - GNSS not always feasible or cost effective
- Some work still needed to fully define the design rules when using PTP in the time sync distribution
  - Control of asymmetry is a key aspect
- PTP cost effectiveness may require the definition of new concepts
  - Increased automation (e.g. automatic compensation of fiber links asymmetry)
  - Control plane may play an important role
  - Shorter BC/TC chains as to limit the impacts of asymmetries
- GNSS will keep a key role
  - “PRTC” of the PTP chain
  - Not all target requirements may be met by means of PTP